Free-standing 3D Nanostar Dimers with Sub-10 nm Gap for Single Molecule Surface Enhanced Raman Scattering

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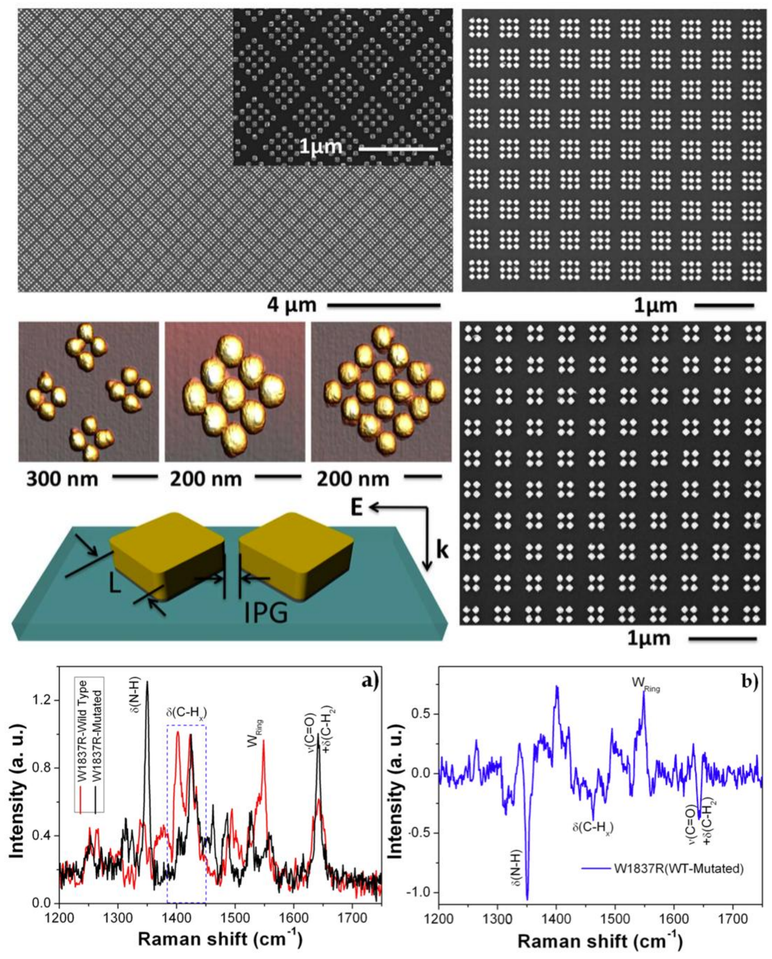
Motivation:

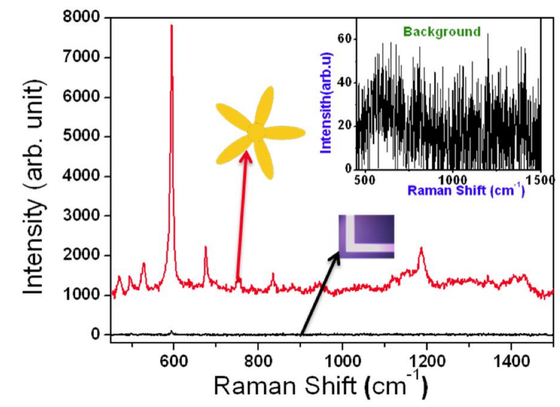
Single molecule detection (SMD) presents extreme importance in several applications, e.g. DNA sequencing, genome detection, single-molecule chemical kinetics and diagnostics. Single molecule surface enhanced Raman spectroscopy (SM-SERS) has received much attention in recent years due to its capability of detecting single/few molecules by enhancing Raman molecular signals using plasmonic nanoparticles/structures as giant amplifiers [1-2]. Therefore, SMD mainly relied on the ability to confine large electromagnetic (EM) fields over tiny gaps or sharp edges i.e. on the possibility of hot-spots engineering. SMD is the utmost sensitivity limit for nanostructures to show their capability in bio-sensing applications.

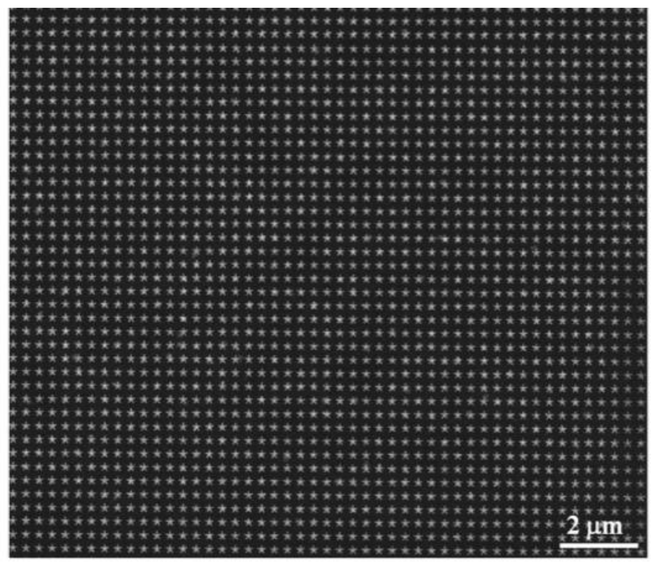
1. Raman measurements on planar-2D nanostructures



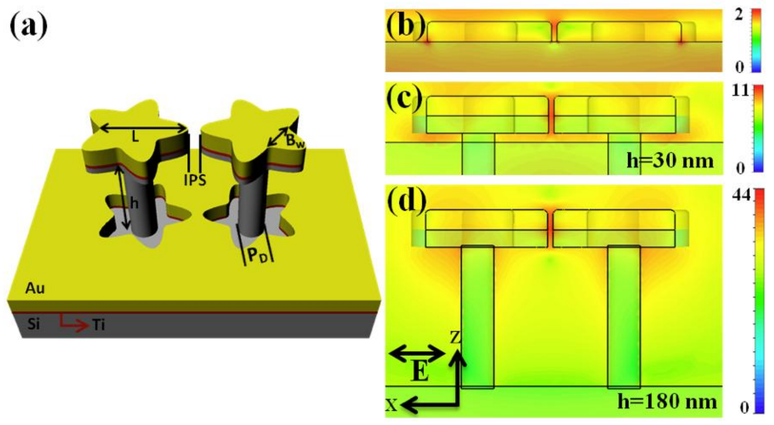
Cuboid for distinguishing peptide mutation states

Array of 2D nanostars as SERS platform

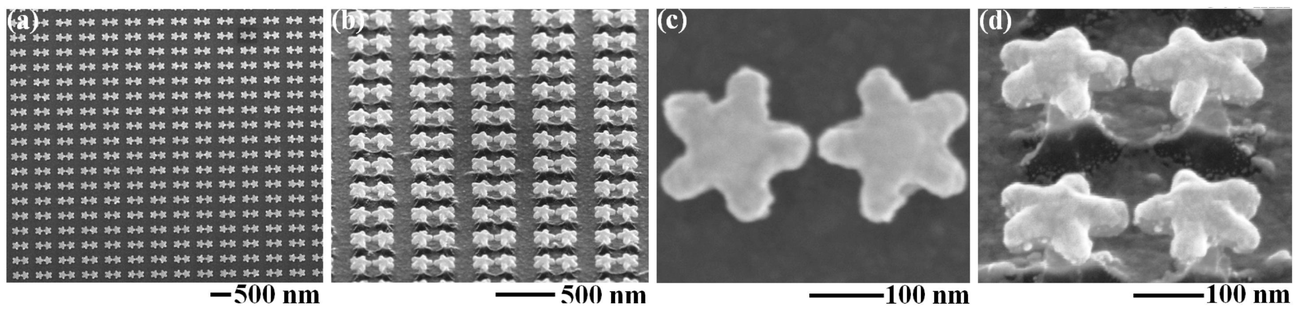




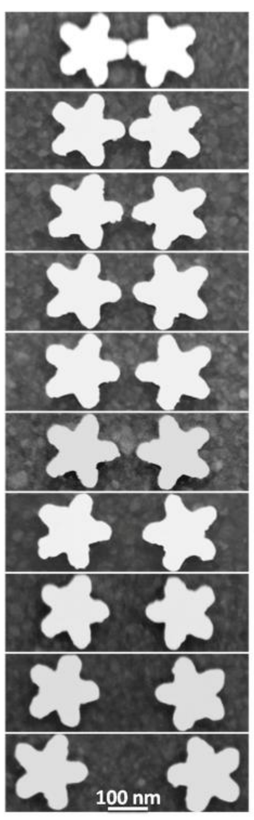
2. Boosting the local Electro Magnetic field: from planar to three-dimensional configuration

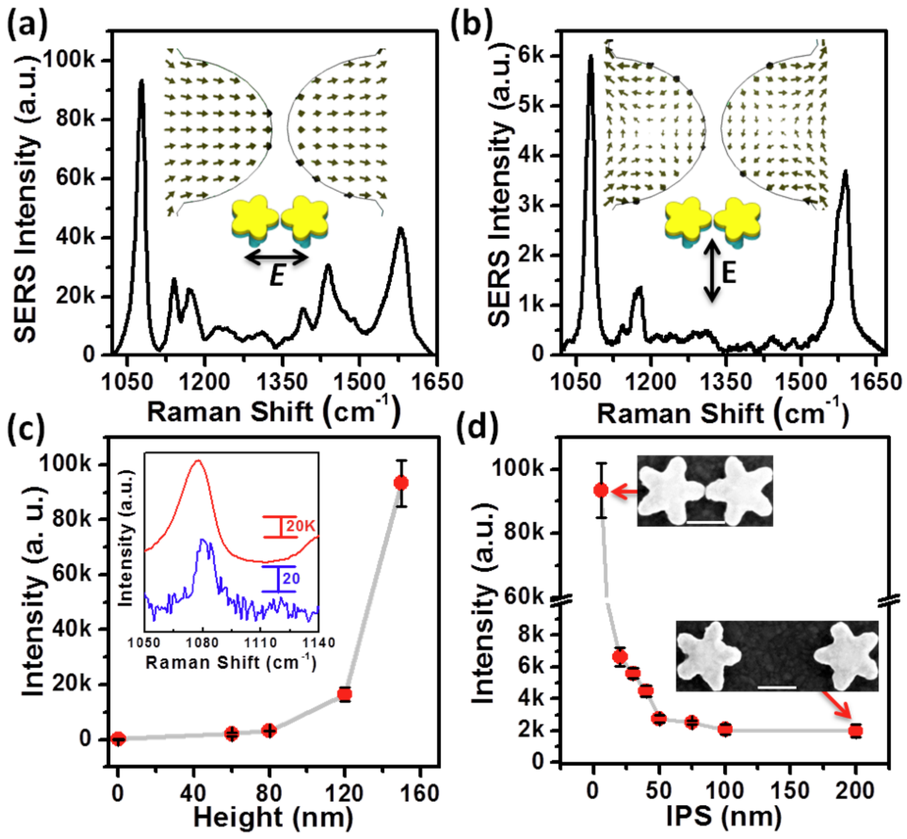


Field distribution as funciotn of structure with 0, 30 and 180 nm Si pillar height



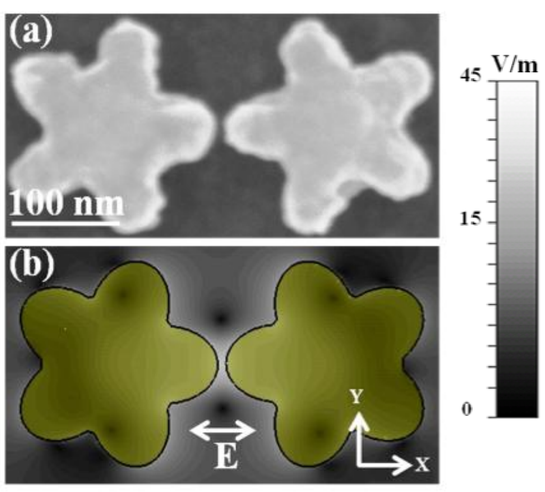
SEM images: NSOP dimers with 6 nm interparticle gap and 150 nm Si pillar height



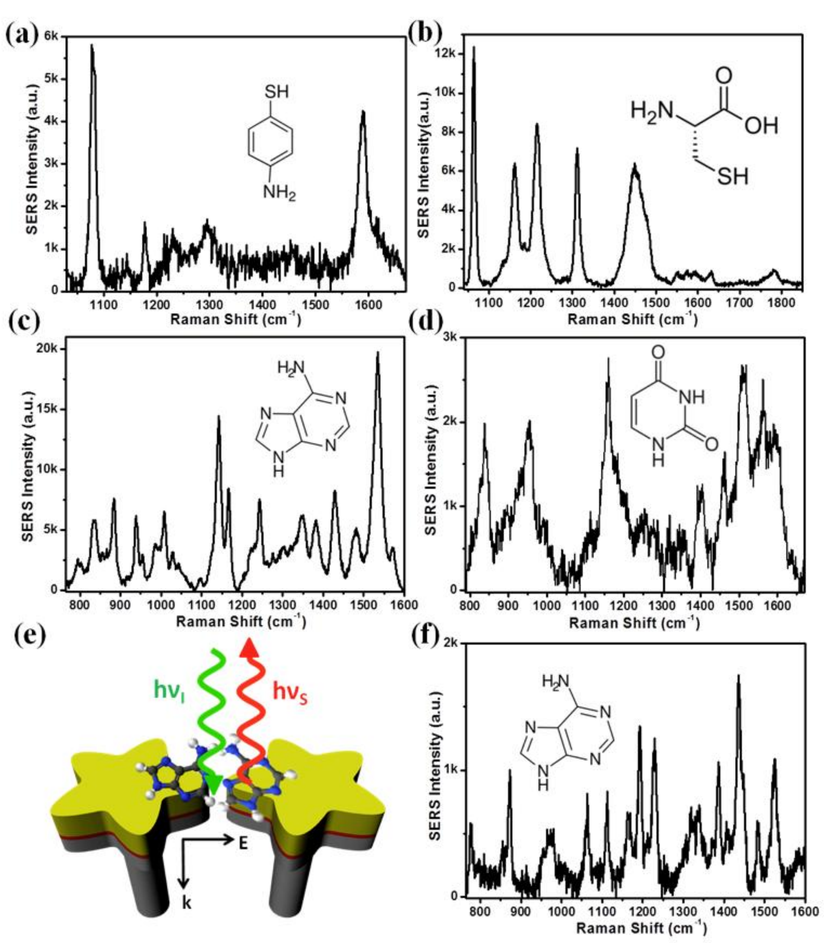


3. SERS on different molecular species (down to pM)

Near-field distribution of the dimer structures. The excitation λ was set to 830 nm with electric field polarized along the x-axis.



(a-f) Typical SERS spectra of p-MA (1 nM), L-cysteine (1 µM), adenine (1 nM), uracil (1 nM) and adenine (1 pM), respectively chemisorbed on NSOP dimers.



Conclusion: various nanostructures (nanocuboids, 2D- and 3D-nanostars) were fabricated and compared (in terms of Raman efficiency) in order to investigate the ultimate limit in bio-sensing applications towards identifying single/few molecules.

References and Insights:

1) ***Nanoscale chemical mapping using three-dimensional adiabatic compression of surface plasmon polaritons***, F. De Angelis et al., Nature Nanotechnology, 5, 67 (2010);
2) ***Breaking the diffusion limit with super-hydrophobic delivery of molecules to plasmonic nanofocusing SERS structures***, F. De Angelis et al., Nature Photonics, 5, 682 (2011);
3) ***Plasmon based biosensor fordistinguishing different peptidesmutation states*** G. Das et al., Scientific reports 3, 1792 (2013).
4) ***3D Nanostar Dimers with sub-10 nm Gap for single/few molecules Surface Enhanced Raman Scattering*** M. Chirumamilla, A. Toma Adv. Mater. (2014) in press.